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Preliminary analysis of human-induced injury and mortality to cetaceans in Atlantic Canada

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Information on human-induced injuries to cetaceans occurring in Atlantic Canada is required to evaluate the effectiveness of recovery strategies for species at risk and to support management decisions on mitigation measures to reduce risk of entanglement of cetacean species from commercial fisheries. Fisheries and Oceans Canada (DFO) undertook an analysis of available data to calculate the average annual rate of human-caused serious injury and mortality of marine mammals (excluding pinnipeds) in Atlantic Canada over the period of 2008 to 2014. Observed incidents of injured and dead cetaceans were compiled from opportunistic sightings of marine mammal strandings and human interactions reported to marine mammal response networks, entanglements recorded by at-sea observers during commercial fishing, and mortalities reported from platforms of opportunity such as Transport Canada pollution patrols and PAL Surveillance flights for DFO Conservation and Protection Division.

More than 800 incidents were reported by marine mammal response networks. Small odontocetes (Pygmy Sperm Whale, White-sided, Common, Risso's, Striped and White-beaked dolphins and Harbour Porpoise) were most commonly reported, followed by baleen whales (North Atlantic Right, Humpback, Minke, Fin, Sei, Blue, and Bowhead whales) and large odontocetes (Beluga, Northern Bottlenose, Sowerby's Beaked, Sperm, and Pilot whales). The animal was reported dead in 65% of all observed incidents and the cause of death was unknown for 80% of these mortalities. A third of all observed incidents were attributable to fishing operations or collisions with vessels. Entanglement in fishing gear was the most common type of incident reported for North Atlantic Right Whale and Humpback Whale and for approximately half of the incidents reported for Minke Whales and Harbour Porpoise. Identifiable gear types were pot and trap (crab or lobster trap), fixed traps (capelin, cod, mackerel, weir), and nets (seine, gillnet). The estimated annual injury rate for North Atlantic Right Whale exceeds the potential biological removal estimated for the population. Fisheries-specific bycatch of small odontocetes could be estimated from at-sea observations of fishing operations, but coverage is low and data were not available from all regions of Atlantic Canada. Standardizing data collection and reporting protocols, prioritizing the collection of detailed information and necropsies, and enhancing the existing national database would improve identifying the causes of human-induced mortality and implementation of mitigating strategies.

Analyse préliminaire des blessures et de la mortalité d'origine anthropique chez les cétacés dans les eaux canadiennes de l'Atlantique

RÉSUMÉ

Il est nécessaire de recueillir des données sur les blessures d'origine anthropique des cétacés dans les eaux canadiennes de l'Atlantique pour évaluer l'efficacité des programmes de rétablissement des espèces en péril, ainsi que pour appuyer les décisions de gestion relatives aux mesures d'atténuation qui visent à réduire le risque d'enchevêtrement d'espèces de cétacés dans le cadre des activités de pêche commerciale. Pêches et Océans Canada (MPO) a entrepris d'analyser les données disponibles afin de calculer le taux annuel moyen de blessures sérieuses et de mortalité d'origine anthropique chez les mammifères marins (à l'exception des pinnipèdes) dans les eaux canadiennes de l'Atlantique au cours de la période allant de 2008 à 2014. Les incidents observés impliquant des cétacés morts ou blessés ont été compilés à partir des échouages de mammifères marins et des interventions humaines signalés aux réseaux d'intervention auprès des mammifères marins, des enchevêtrements notés par des observateurs en mer lors d'activités de pêche commerciale, et des cas de mortalité signalés par l'intermédiaire de plateformes de passage, telles que les patrouilles de surveillance antipollution de Transports Canada et les vols de surveillance aérienne PAL effectués par la Division de la conservation et de la protection du MPO.

Les réseaux d'intervention auprès des mammifères marins ont signalé plus de 800 incidents. Les incidents impliquant des petits odontocètes (cachalot pygmée, dauphin à flancs blancs, dauphin commun, dauphin de Risso, dauphin bleu, dauphin à bec blanc et marsouin commun) ont été les plus fréquemment signalés, suivis des incidents impliquant des baleines à fanons (baleine noire de l'Atlantique Nord, rorqual à bosse, petit rorqual, rorqual commun, rorqual boréal, rorqual bleu et baleine boréale) et de grands odontocètes (béluga, baleine à bec commune, baleine à bec de Sowerby, cachalot et globicéphale noir). Dans 65 % des incidents observés, l'animal était mort, mais la cause de la mortalité était inconnue dans 80 % de ces cas. Le tiers des incidents étaient imputables à des activités de pêche ou à des collisions avec des navires. L'enchevêtrement dans des engins de pêche était le type d'incident le plus communément signalé dans le cas de la baleine noire de l'Atlantique Nord et du rorqual à bosse; ce type d'incident compte également pour près de la moitié des incidents signalés impliquant le petit rorqual ou le marsouin commun. Les types d'engin impliqués dans ces incidents sont les casiers ou pièges (pour la pêche du crabe ou du homard), les casiers fixes (capelan, morue, maquereau, fascine) et les filets (seine, filet maillant). Le taux annuel estimatif de blessure de la baleine franche de l'Atlantique Nord est supérieur au prélèvement biologique potentiel pour cette espèce. Les prises accessoires d'espèces de petits odontocètes pour chaque pêche pourraient être estimées à partir des rapports des observateurs en mer, mais il y a peu d'observations et l'on ne dispose pas de données pour toutes les régions du Canada atlantique. La normalisation des protocoles de collecte de données et de production de rapports, la priorisation des nécropsies et de la collecte de renseignements détaillés, ainsi que l'amélioration de la base de données nationale sont autant de mesures qui permettraient de cerner avec plus de précision les causes de mortalité d'origine anthropique et de mettre en œuvre des stratégies d'atténuation.

INTRODUCTION

Human-induced injury and mortality to cetaceans are well documented for most species (Read 2008; Young and Ludicello 2007; Ross et al. 2011). Vessel strikes, interactions with fishing gear, human interactions, acoustic disturbances and even marine pollution have proven injurious or fatal to many species and all or some of these are listed as threats to species recovery for Atlantic Canadian cetaceans protected under the *Species at Risk Act* (SARA) [North Atlantic Right Whale (DFO 2014), Scotian Shelf population of Northern Bottlenose Whale (DFO 2010), Atlantic Blue Whale (Beauchamp et al. 2009) and the St. Lawrence estuary population of Beluga Whale (DFO 2012)]. Cetaceans reported stranded or entangled in fishing gear in Canadian waters include mysticetes (baleen whales) and odontocetes (toothed whales, dolphins and Harbour Porpoise) (Henry et al. 2015; Hooker et al. 1997; Nemiroff et al. 2010; Reeves et al. 2013). An objective of all recovery strategies published for Atlantic Canadian cetaceans protected under SARA is to restore self-sustaining populations and for populations to reach a recovery target number where this can be achieved. Continued anthropomorphic injuries and mortalities are likely to have negative effects on recovery targets. Calculating these effects is difficult for many Atlantic Canadian cetacean species because of a lack of detailed data on injuries and mortalities, as well as a lack of population estimates for all species except the North Atlantic Right Whale and Northern Bottlenose Whale (O'Brien and Whitehead 2013). Detailed information on the causes of these injuries and mortalities to cetaceans in Atlantic Canadian coastal waters is required to evaluate the effectiveness of recovery strategies for species at risk and to support management decisions on measures to mitigate entanglement risk to cetacean species from commercial fisheries.

Implementation of the U.S. *Marine Mammal Protection Act* (MMPA) and its impact on Canadian fisheries exporting seafood into U.S. markets is an additional incentive for estimating species-specific human-induced injuries in Atlantic Canada. Enacted in 1972, the MMPA prohibits the taking of marine mammals in U.S. waters and by U.S. citizens on the high seas and also prohibits the importation of marine mammals and products into the U.S. amendments to the MMPA in 1994 included: a program to authorize and control the taking of marine mammals incidental to commercial fishing operations and preparation of stock assessments for all marine mammal stocks in waters under U.S. jurisdiction. The MMPA requires the U.S. Federal government to estimate annual levels of human-induced serious injury and mortality to marine mammal stocks and to categorize foreign commercial fisheries based on their level of incidental serious injury to and mortality of marine mammals. This would have implications on the export of Canadian fisheries products into the U.S. by requiring foreign fisheries to meet the same marine mammal protection standards required of U.S. fishermen.

The objectives of this study were to gather information from available data sources on injuries to and mortalities of cetaceans in Atlantic Canadian waters from 2008-2014; identify the cetaceans most commonly reported injured or dead; determine the types of fishing activities that cause the most injuries and mortality; and compare the average annual rate of injury of North Atlantic Right Whale to the Potential Biological Removal (PBR) estimated for this species. Addressing these objectives will help determine the level or risk of threats identified in SARA recovery plans and identify high risk fisheries and vulnerable marine mammals.

METHODS

Incidents of injured, entangled and dead cetaceans observed in Atlantic Canada from 2008-2014 were compiled from two types of data sources. The first were opportunistic sightings of marine mammal strandings and human interactions collected by marine mammal response

networks and the second source of data was the At-sea Observer programs. At-sea fishery observers record incidental catches of cetaceans during commercial fishing operations. Four DFO regions share responsibility for managing Canada's Atlantic Ocean resources: Quebec, Gulf, Maritimes and Newfoundland and Labrador (Fig. 1) and the observer databases are maintained regionally.

OPPORTUNISTIC SIGHTINGS DATA

Opportunistic sightings are marine mammal incidents reported by any observer to a responsible body (DFO or marine mammal response network). These reports are truly based on "right place, right time" observations and do not include any surveys or monitoring data. Currently, there are no Canadian federal or provincial programs that regularly monitor or survey marine waters in search of marine animals in distress. As such, most incidents are reported by private, provincial and federal government ships, commercial vessels and members of the general public. This report relied heavily on opportunistic sightings reported to response networks, organizations that operate with limited funding and capacity for responding to all incidents. Not all incidents are easily accessible (e.g. floating whale carcasses) and some carcasses are not in good enough condition to examine. Incident data are fairly comprehensive in some cases and even include necropsy reports while other incidents may be data deficient and limited with respect to the date, possible species identification and the state of animal observed (e.g. floating carcass) only. These data cannot be used to determine fishery-specific rates because the incidents reports are not effort-based, do not always contain data on the specific gear associated with the incident, and are not directly linked to monitoring of specific fishing activities.

Several marine mammal response networks operate throughout Atlantic Canada. Each network collects information on the species, type of incident, location and causes of injury. Some networks have been collecting data as far back as 1979 and cetacean strandings in the Maritimes from 1990-2008 have been summarized (Hooker et al. 1997; Nemiroff et al. 2010). Since 2008, the networks have provided annual reports to a national DFO database, the National Marine Mammal Response Program (MMRP). The quality and detail of the data in the MMRP vary by year due to differences in the state of the animal, circumstances of the incident as well as data collection and reporting protocols between networks, and the gradual development of the MMRP. For this report, the data provided by the response organization was the primary source and events recorded in the MMRP were only included when no matching record was found in the response network records.

Marine Animal Response Society (MARS): In the Maritimes and Gulf regions, a network of 11 governmental and non-governmental organizations are responsible for organizing, coordinating and implementing measures aimed at reducing accidental mortality of marine mammals, responding to marine mammals in difficulty, and facilitating data collection from dead animals (the Maritime Marine Animal Response Network, MMARN). The Marine Animal Response Society (MARS) operates the toll-free reporting hotline and, where possible, coordinates MMARN response activities. Reports of incidents are obtained from many sources including the public and fishermen about entanglements, strandings, beached carcasses and sightings of live and dead marine animals. Disentanglements of cetaceans on the water are mainly conducted by the Campobello Whale Rescue Team (CWRT) based on Campobello Island, New Brunswick. The Grand Manan Whale and Seabird Research Station (GMWSRS) also respond to incidents of Harbour Porpoise and whales trapped in weirs in the Bay of Fundy. MARS provides quarterly reports of incidents involving cetaceans and disentanglement attempts to the MMRP. MARS also provides data on transboundary stocks of cetaceans to the Northeast Fisheries Science Centre (NEFSC) of the National Marine Fisheries Service (NMFS) for inclusion in their multi-year summaries of serious injuries and mortalities occurring to large whales in Atlantic Canada

and along the U.S. eastern seaboard (Cole and Henry 2013; Glass et al. 2009; Henry et al. 2012, 2014, 2015) and stock assessment reports.

DFO Maritimes Whale Sighting Database (WSDB): DFO Maritimes maintains a database to collect information on large marine animal sightings and marine mammal surveys from the Scotian Shelf, Bay of Fundy and other areas of Eastern Canada. The WSDB contains data from opportunistic sightings of live animals reported by the public and whale watching companies that are reported through a toll-free phone or email, sightings during aerial and ship surveys and observer reports from commercial fishing, as well as some records of strandings, floating carcasses and fishing gear interactions. DFO Maritimes does not report information from their databases to the MMRP.

Whale Release and Strandings Group (WRS or Tangly Whales Inc): In the Newfoundland and Labrador Region, WRS maintains a toll-free number for reporting beached or entangled marine animals. The group responds to reports of strandings and entanglements and assists fishers in releasing whales, sea turtles and basking sharks caught in fishing gear, and respond to live strandings of marine animals, with cooperation from DFO Newfoundland and Labrador. The WRS also records and monitors information from fishers about whale interactions, including entanglements, sightings and strandings. Responses and records from the WRS are summarized in annual reports to DFO Newfoundland and Labrador and the Newfoundland and Labrador Department of Fisheries. The WRS also provides data for the annual reports produced by the NEFSC and to the MMRP. For this report, Newfoundland and Labrador records from 2008-2013 were obtained from the MMRP database cross-checked with NEFCS reports. Activities conducted in 2014 were described in a WRS 2014 report (Ledwell, Huntingdon and Sacrey, unpubl. data).

DFO Newfoundland Marine Mammal Database: Whale sightings in Newfoundland and Labrador may be reported through email to DFO NL (jack.lawson@dfo-mpo.gc.ca or TellJack@dfo-mpo.gc.ca), for example, whale carcasses observed during Environment Canada aerial pollution surveys. There are no formal protocols for sharing reports between DFO Newfoundland and Labrador and the MMRP or other databases maintained by DFO, although a national sightings database format has been created by the National Sightings Data Management Group.

Quebec Marine Mammal Emergency Response Network (RQUMM, baleinesendirect.org): In Quebec Region, a network of 18 governmental and non-governmental organizations is responsible for organizing, coordinating and implementing measures aimed at reducing accidental mortality of marine mammals, rescuing marine mammals in difficulty, and facilitating data collection from dead animals. The Group for Research and Education on Marine Mammals (GREMM) operates a call centre to respond to reports of marine animal incidents and collect data. Annual reports by GREMM to the MMRP on marine mammal incidents were supplemented with records sent directly from GREMM of cetaceans observed injured or dead from 2008-2014 and the type of incident. Not all of these records were duplicated by the MMRP database, specifically some incidents involving vessels colliding with whales.

AT-SEA OBSERVER DATA

At-sea fishery observers record incidental catches of cetaceans during fishing operations. These data are not recorded by the MMRP. Observer data are effort based and are useful for estimating fishery-specific cetacean bycatch rates with estimates of uncertainty. Each DFO region maintains its own fishery observer program. At-sea observations of interactions between cetaceans and fishing gear were available only from Maritimes and Quebec regions.

SERIOUS INJURY DETERMINATION

Data from all sources for injuries were compiled and were used to identify the species or family of the species (baleen, toothed) and injury to the animal was assigned one of three outcomes for each incident: alive; alive and injured; dead. *Alive* was assigned if the animal was reported alive and associated with fishing gear and there was no information on the outcome (most 'alive' records), the animal was freed and had no visible injuries, or NMFS reports indicated the animal was observed later and appeared healthy. *Alive and injured* animals had injuries described as severe and the incident was confirmed and published by the NMFS [which has an established protocol for assessing injury (Henry et al. 2015)]; the injuries were confirmed by a response network; or a disentanglement team reported that the animal was severely entangled and could not be disentangled. *Dead* animals were confirmed dead by a response network as well as incidents where the animal was reported as beached or stranded, or a floating carcass. In some instances, incident records of dead, beached or floating carcasses indicated that a necropsy was planned or completed, but the outcome of the necropsy was not recorded.

Anthropogenic Causes of Injury and Mortality

Vessel strike as a source of injury was based on the cause assigned by the marine mammal response networks. Incidents involving large whales in the Bay of Fundy, Scotian Shelf and Newfoundland waters were published in NMFS reports. Incidents reported in the Quebec Region and recorded by GREMM or MMRP had no detail on the nature of the injury. Fishing gear was identified as the source of the incident if the animal was observed entangled or entrapped in any kind of gear intended to catch fish or invertebrates. The kind of gear was indicated if the gear type was identifiable, for example, the animal was dragging gillnets, lobster pots or marked buoys, or entangled in a trap. The type of gear was unknown if the animal was carrying only rope and buoys or had injuries or scars indicating contact with fishing gear or lines.

RESULTS

OPPORTUNISTIC SIGHTINGS

More than 800 incidents involving 19 cetacean species were reported by marine mammal response networks in Atlantic Canada from 2008-2014 (Table 1). Incidents involving small odontocetes (Pygmy Sperm Whale, White-sided, Common, Risso's, Striped and White-beaked dolphins and Harbour Porpoise) were most commonly reported, followed closely by baleen whales (Right, Humpback, Minke, Fin, Sei, Blue and Bowhead Whales) and large odontocetes (Beluga, Northern Bottlenose, Sowerby's Beaked, Sperm and Pilot Whales).

Two-thirds of all incidents reported were of floating carcasses or beachings, and strandings of both live and dead animals. A third of all observed incidents were attributable to fishing operations or collisions with vessels. In 65% of all incidents, the animal was reported dead, and in 80% of those incidents involving mortalities, the cause of death was unknown. Two events of large numbers of animals trapped and dying in pack ice were reported in 2014, one involving nine Blue Whales and the other 40 White-beaked Dolphins.

Entanglement in fishing gear was the most common type of incident reported for Right Whale (95% of incidents) and Humpback Whale (85% of incidents). Almost half of the reports for Minke Whale (n=47) and Harbour Porpoise (n=78) were also related to entanglements in fishing gear (Table 2). Other baleen whales and both large and small odontocetes, were most likely to be reported as floating or beached carcasses or in stranding events (55-95% of reports).

Collisions between cetaceans and vessels were reported infrequently, with only seven observed incidents from 2008-2014 (Table 2). One of these was a Right Whale struck in the Bay of Fundy in 2009 that has since been resighted and appeared healthy (Henry et al. 2015). An unidentified whale was struck by a 24 m sailboat on the Scotian Shelf off Cape Sable Island, Nova Scotia, in 2013. Four vessel strikes were reported from the Quebec Region: a Fin Whale, two Blue Whales and a Sei Whale. The fate of these animals was unknown except for the Sei Whale that was confirmed dead.

A total of 274 incidents involving cetaceans and fishing gear were recorded (Table 2). Harbour Porpoise and baleen whales (Humpback, Minke, Right and Fin whales), were the species most commonly reported entangled or trapped in fishing gear. Humpback Whales had the highest average human induced injuries per year, followed by Minke Whales and Right Whales. Although a large number of Harbour Porpoise were entrapped in Bay of Fundy herring weirs, joint rescue efforts by commercial fishermen and GMWSRS were successful in minimizing mortalities. Species never recorded entangled in fishing gear by the response networks were Bowhead, Beluga, Blue and Pygmy Sperm whales and Atlantic White-sided and Striped dolphins.

Gear Types

Gear types identified in cetacean entanglements and entrapments reported by response networks were pot and trap (crab or lobster trap), fixed traps (capelin, cod, mackerel, weir), and nets (seine, gillnet) (Table 3). The entangling gear (ropes, buoys) could not be identified to a fishery in 78% (n=14) of the incidents reported for Right Whales and 35-100% of the incidents involving other baleen whales. Entanglements in fishing gear of large odontocetes were infrequently reported to response networks. Apart from Harbour Porpoise, response networks reported few interactions (n=4) between small odontocetes and fishing gear.

AT-SEA OBSERVER DATA

A total of 28 cetaceans were reported entangled in fishing gear by at-sea observers operating in the DFO Maritimes and DFO Quebec regions (Table 4). Two were baleen whales (one Bowhead and one Humpback), six were large odontocetes (Beluga and Pilot whales), and one was identified only as an unspecified whale. The remaining 19 animals were small odontocetes (White-sided, Risso's, Common and Bottlenose dolphins and Harbour Porpoise) with two-thirds reported in bottom otter trawl gear. Other species-gear interactions observed were Bowhead Whale with bottom otter trawl, Pilot Whales with bottom otter trawl and pelagic longline, dolphins with gillnet, pelagic longline and scallop drag and Harbour Porpoise with gillnets. The one Humpback Whale became entangled during retrieval of crab pots and was freed from most of the gear by the crew.

COMPARISON WITH POTENTIAL BIOLOGICAL REMOVAL (PBR) ESTIMATES

Corrected abundance estimates for most cetacean species in Atlantic Canada are available (Lawson and Gosselin 2009), but the potential threat from anthropogenic activities has not been assessed. The two exceptions are Northern Bottlenose Whale and Right Whale. The PBR for the Scotian Shelf population of Northern Bottlenose Whales is 0.3 animals per year (DFO 2007), based on a population size estimate that has since declined (Whitehead and Wimmer 2005; O'Brien and Whitehead 2013). The Right Whale migrates seasonally between U.S. and Canadian jurisdictions, and both DFO and NMFS have programs to monitor entanglements by this species in fishing gear. The estimated injury rate for the Canadian Atlantic in this study is 1.7 Right Whales per year (based on opportunistic sightings data), which exceeds the PBR of 0.9 estimated for this species (Waring et al. 2015).

DISCUSSION

Opportunistic data are important for recording interactions by baleen whales and large toothed whales with fishing gear. The commercial fisheries observed to incidentally entangle large whales (groundfish gillnets, fish traps, weirs, lobster, snow crab) have little or no at-sea observer coverage (Gavaris et al. 2010). Also, large whales can drag gear and swim away before they are detected at the original entanglement location. Some of these fisheries (gillnets, longline, crab and lobster trap) have been shown to have the highest potential for Right Whale entanglement in the Bay of Fundy, due to the overlap between the summer distribution of the whales and the deployment of gear (Johnston et al. 2007; Vanderlaan et al. 2014). Gear from lobster fisheries pose the greatest threat during the spring and autumn periods when the whales are migrating to and from their summer habitat (Vanderlaan et al. 2014). If the recently observed shift in the summer distribution of Right Whale to the Gulf of St. Lawrence persists, the potential for interactions will increase between Right Whales and fixed gear deployed in the Gulf of St. Lawrence and on migration routes across the Scotian Shelf. These areas are an area of concern for other migrating cetaceans.

Opportunistic data collection would be improved through increasing the number and geographic distribution of reports and the detail of reporting. Regional response networks and DFO are acting on this by distributing information leaflets and posters publicizing the role of response networks and directing observers to call toll-free phone lines and report distressed, entangled or dead cetaceans. Mariners and recreational boaters can use a software application, WhaleAlert, to report whale sightings and incidents with a smart phone; however, these reports do not go directly to a Canadian database nor are they in real time. Standardizing and centralizing the storage of data will improve the ability to monitor and report on trends in the incidence of entanglements for the entire Canadian Atlantic; a task that, as this study shows, is complicated by multiple databases and regional at-sea observer programs.

Currently, the cause of death is not known for more than 80% of all reported cetacean carcasses. The level of detail reported for an incident has improved as the reporting protocols and databases maintained by the response networks and DFO have matured. Monitored phone lines provide an active response, timely information on the location of cetaceans, the possibility of disentanglement, and useful information on the cause and extent of injuries. Quick dispatch of experts by response networks to reports of beached or floating carcasses and live distressed animals; interviews of witnesses; and the collection of photographs increase the likelihood of determining whether a mortality is natural or human-induced. Close inspection by trained experts can reveal scars left by fishing lines even when no gear is present (indicating previous entanglements) and large linear lacerations indicative of vessel collisions (Henry et al. 2014). Detailed photographic evidence and necropsies has enabled NMFS to assess the seriousness of human-induced injuries and monitor the recovery of baleen whales from entangling events.

Conducting necropsies on any and all species should be a priority for increasing the usefulness of response network data. Prioritizing examination of beached and floating carcasses, as well as entangled animals, would aid in increasing the proportion of known causes of mortality. Carcasses encountered at sea often cannot be examined sufficiently to detect internal or external indications of anthropogenic injury (Henry et al. 2014), unless they are retrieved and towed to a secure location. Right Whales carcasses found floating in U.S. waters are brought to shore where possible for necropsy (Moore et al. 2007). Conducting necropsies has been identified as a priority in recovery strategies for listed marine species found in Canadian waters, such as Right Whales (DFO 2014). The results of necropsies, for all cetacean species, should become part of the incident record available to DFO.

Researchers have concluded that the probability of detecting more than a fraction of injuries and mortalities due to natural or anthropogenic sources is low (Robbins 2011, 2012; Williams et al. 2011) and, together with inadequate documentation, means that the level of human impact to whales is greater than reported (Henry et al. 2015). Whales entangled for a long time before dying may be more likely to sink at sea because of the decreased health of the animals and subsequent loss of blubber mass (Kraus et al. 2005; Moore et al. 2007). It has been suggested that up to two-thirds of human-caused Right Whale deaths may go undetected for this reason (Moore et al. 2005). Based on the low numbers of cetacean carcasses observed following an oil spill in the Gulf of Mexico, Williams et al. (2011) recommend developing a framework accounting for the low probability of recovering carcasses to assess the consequence of activities causing cryptic mortality, such as vessel strikes, fisheries interactions and acoustic trauma.

Fisheries-specific bycatch cannot be estimated from opportunistic data because the degree of reporting is dependent on the density of observers on the water and the effectiveness of campaigns directing observers to phone lines monitored by response networks. Thus, these data only provide minimum estimates of human-induced injury rates that are biased on the low side.

Fisheries-specific bycatch of small odontocetes could be estimated from at-sea observations of fishing operations. Observed injuries and mortalities would need to be scaled up to estimate entanglements by the entire fleet; however, the observer coverage is very low, especially for fixed gear (longline, gillnet). For example, observer coverage in southwest Nova Scotia and Bay of Fundy from 2007-2011 varied (percent of all fishing trips) from 2.4-10.7% in bottom otter trawl, 0-1.8% in gillnet and 1.8-5.7% in longline (Clark et al. 2015).

The bycatch of Harbour Porpoise reported is likely greatly underestimated and may be substantial based on published estimates. Only a single Harbour Porpoise entanglement was reported for DFO Maritimes Region, and no observer data were available from the DFO Gulf and DFO Newfoundland and Labrador regions. Previous investigations have indicated that Harbour Porpoise are particularly vulnerable to inshore fisheries deploying fixed gillnets and traps (Read 1994). Other published estimates of Harbour Porpoise bycatch from Atlantic Canada are substantially higher than what is reported here; for example, annual catches of Harbour Porpoise in gillnet fisheries in Newfoundland and Labrador were estimated at 862-2,228 animals from 2001-2003 (Benjamins et al. 2007).

In addition to documenting observations of dead and injured cetaceans, response networks, where possible, also respond to and mitigate entanglement and entrapment of cetaceans. For example, the Harbour Porpoise release program developed by the GMWSRS has had a high success rate in releasing trapped porpoises from herring weirs without injury to the animals or gear. A positive effect of monitoring and supporting emergency response and disentanglement programs is that prompt intervention and disentanglement have been shown to improve the survival outcome of entangled Right Whales (Robbins et al. 2015).

Opportunistic and at-sea observer data are useful for providing a qualitative view of the fisheries that interact with cetaceans, the rates of interactions, and those species that may be most vulnerable to a particular type of gear. Increased at-sea observer coverage is required to calculate fishery-specific bycatch rates and estimates of uncertainty for small cetaceans. This study relied heavily on opportunistic data that only provide a minimum estimate of cetacean injuries and mortality. Most incidents are unobserved or unreported and the rates of entanglement and injury to large whales from fishing gear interactions and vessel strikes have been shown to have increased (Knowlton et al. 2012; van der Hoop et al. 2012; Pace et al. 2014).

Assessment of the sources and degree of human-induced injuries to cetaceans in Atlantic Canada is incomplete and difficult with the data currently available and would be improved by enhancement of the MMRP, or a similar national network to receive annual reports on cetacean strandings and entanglements. Standardizing data collection and reporting protocols among DFO regions should be implemented, as well as including effort based data from regional observer programs. Emphasis on collecting detailed information to include with incident reports (photographs, witness interviews, necropsies) will aid in determining the source of cetacean injuries. Currently, the capacity to collect data on incidents and to respond to entanglements resides mainly with response networks. Supporting their efforts to respond adequately to incidents and developing information sharing protocols may be beneficial to DFO for monitoring anthropogenic impacts on cetaceans.

REFERENCES

Beauchamp, J., Bouchard, H., de Margerie, P., Otis, N., and Savaria, J.-Y. 2009. Recovery Strategy for the Blue Whale (*Balaenoptera musculus*), Northwest Atlantic population, in Canada [FINAL]. *Species at Risk Act* Recov. Strat. Ser., Fisheries and Oceans Canada, Ottawa. 62 p.

Benjamins, S., Lawson, J., and Stenson, G. 2007. Recent Harbour Porpoise bycatch in gillnet fisheries in Newfoundland and Labrador. J. Cetacean Res. Manage. 9(3): 189-199.

Clark, K.J., Hansen, S.C., and Gale, J. 2015. Overview of discards from Canadian commercial groundfish fisheries in Northwest Atlantic Fisheries Organization (NAFO) Divisions 4X5Yb for 2007-2011. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/054.

Cole, T.V.N., and Henry A.G. 2013. Serious injury determinations for baleen whale stocks along the Gulf of Mexico, United States East Coast and Atlantic Canadian Provinces, 2007-2011. U.S. Dept Commer., Northeast Fish. Sci. Cent. Ref. Doc. 13-24. 14 p.

DFO. 2007. Recovery potential assessment of Northern Bottlenose Whale, Scotian Shelf population. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/011.

DFO. 2010. Recovery Strategy for the Northern Bottlenose Whale, Scotian Shelf population, in Atlantic Canadian Waters. *Species at Risk Act* Recov. Strat. Ser., Fisheries and Oceans Canada, Ottawa. vi + 61 p.

DFO. 2012. Recovery Strategy for the beluga whale (*Delphinapterus leucas*) St. Lawrence Estuary population in Canada. *Species at Risk Act* Recov. Strat. Ser., Fisheries and Oceans Canada, Ottawa. 88 p.

DFO. 2014. Recovery Strategy for the North Atlantic Right Whale (*Eubalaena glacialis*) in Atlantic Canadian Waters [Final]. *Species at Risk Act* Recov. Strat. Ser., Fisheries and Oceans Canada, Ottawa. vii + 68 p.

Gavaris, S., Clark, K.J., Hanke, A.R., Purchase, C.F., and Gale, J. 2010. Overview of discards from Canadian commercial fisheries in NAFO Divisions 4V, 4W, 4X, 5Y and 5Z for 2002-2006. Can. Tech. Rep. Fish. Aquat. Sci. 2873: vi + 112 p.

Glass, A.H., Cole, T.V.N., and Garron, M. 2009. Mortality and serious injury determinations for baleen whale stocks along the United States eastern seaboard and adjacent Canadian maritimes, 2003-2007. U.S. Dept Commer., Northeast Fish. Sci. Cent. Ref. Doc. 09-04. 19 p.

Henry, A.G., Cole, T.V.N., Garron, M., Hall, L., Ledwell, W., and Reid, A. 2012. Mortality and serious injury determinations for baleen whale stocks along the Gulf of Mexico, United States east coast and Atlantic Canadian provinces, 2006-2010. U.S. Dept Commer. Northeast Fish. Sci. Cent. Ref. Doc. 12-11. 24 p.

Henry, A.G., Cole, T.V.N., Hall, L., Ledwell, W., Morin, D., and Reid, A. 2014. Mortality determinations for baleen whale stocks along the Gulf of Mexico, United States east coast and Atlantic Canadian provinces, 2008-12. U.S. Dept Commer., Northeast Fish. Sci. Cent. Ref. Doc. 14-10. 17 p.

Henry, A.G., Cole, T.V.N., Hall, L., Ledwell, W., Morin, D., and Reid, A. 2015. Serious injury determinations for baleen whale stocks along the Gulf of Mexico, United States east coast and Atlantic Canadian provinces, 2009-2013. Northeast Fish. Sci. Cent. Res. Doc. 15-10. 45 p.

Hooker, S.K., Baird, R.W., and Showell, M.A. 1997. Cetaceans strandings and bycatches in Nova Scotia, Eastern Canada. . IWC Doc. SC/49/05. 11 p.

Johnston, T.L., Smedbol, R.K., Serdynska, A., Vanderlaan, A., Helcl, N., Harris, L., and Taggart, C.T. 2007. Patterns of fishing gear in areas of the Bay of Fundy and southwest Scotian Shelf frequented by North Atlantic Right Whales. Can. Tech. Rep. Fish. Aquat. Sci. 2745: v + 52 p.

Kraus, S.D., Brown, M.W., Caswell, H., Clark, C.W., Fujirara, M., Hamilton, P.K., Kenney, R.D., Knowlton, A.R., Landry, S., Mayo, C.A., McLellan, W.A., Moore, M.J., Nowacek, D.P., Pabst, D.A., Read, A.J., and Rolland, R.M. 2005. North Atlantic Right Whale in crisis. Science 309:561–562.

Knowlton, A.R., Hamilton, P.K., Marx, M.K., Pettis, H.M., and Kraus, S.D. 2012. Monitoring North Atlantic Right Whale *Eubalaena glacialis* entanglement rates: A 30 yr retrospective. Mar. Ecol. Prog. Ser. 466: 293–302.

Lawson. J.W., and Gosselin, J.-F. 2009. Distribution and preliminary abundance estimates for cetaceans seen during Canada's marine megafauna survey - A component of the 2007 TNASS. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/031.

Moore, M.J., Knowlton, A.R., Kraus, S.D., McLellan, W.A., and Bonde, R.K. 2005. Morphometry, gross morphology and available histopathology in North Atlantic Right Whale (*Eubalaena glacialis*) mortalities (1970–2002). J. Cetacean Res. Manag. 6:199–214.

Moore, M.J., McLellan, W.A., Daoust, P.-Y., Bonde, R.K., and Knowlton, A.R. 2007. Right Whale mortality: A message from the dead to the living (pp. 358-379). *In* Kraus, S.D. and Rolland, R.M. (editors). The urban whale: North Atlantic Right Whales at the crossroads. Harvard University Press, Mass.

Nemiroff, L., Wimmer, T., Daoust, P.-Y., and McAlpine, D.F. 2010. Cetacean strandings in the Canadian Maritime provinces, 1990–2008. Can. Field-Nat.124: 32–44.

O'Brien, K., and Whitehead, H. 2013. Population analysis of endangered Northern Bottlenose Whales on the Scotian Shelf seven years after the establishment of a Marine Protected Area. Endang. Species Res. 21: 273-284.

Pace, R.M., Cole, T.V.N., and Henry, A. 2014. Incremental fishing gear modifications fail to significantly reduce large whale serious injury rates. Endang. Species Res. 26: 115-126.

Read, A.J. 1994. Interactions between cetaceans and gillnet and trap fisheries in the northwest Atlantic. Gillnets and cetaceans. Rep. Int. Whal. Comm. Spec. Iss. 15: 133-147.

Read, A.J. 2008. The looming crisis: Interactions between marine animals and fisheries. J. Mammal. 89: 541-548.

Reeves, R.R., McClellan, K., and Werner, T.B. 2013. Marine mammal bycatch in gillnet and other entangling net fisheries, 1990 to 2011. Endang. Species Res. 20: 71-97.

Robbins, J. 2011. Scar-based inference into Gulf of Maine Humpback Whale entanglement: 2009. Order no. EA133F09CN0253. Rept. Nat. Marine Fish. Service, Woods Hole, MA.

Robbins, J. 2012. Scar-based inference into Gulf of Maine Humpback Whale entanglement: 2010. Order no. EA133F09CN0253. Rept. Nat. Marine Fish. Service, Woods Hole, MA.

Robbins, J., Knowlton, A.R., and Landry, S. 2015. Apparent survival of North Atlantic Right Whales after entanglement in fishing gear. Biol. Cons. 191: 421-427.

Ross, P.S., Barlow, J., Jefferson, T.A., Hickie, B.E., Lee, T., MacFarquhar, C., Parsons, E.C., Riehl, K.C., Rose, N.A., Slooten, E., Tsai, C.-Y., Wang, J.Y., Wright, A.J., and Yang, S.C. 2011. Ten guiding principles for the delineation of priority habitat for endangered small cetaceans. Mar. Pol. 35: 483-488.

Vanderlaan, A.S.M, Smedbol, R.K., and Taggart, C.T. 2014. Fishing-gear threat to Right Whales (*Eubalaena glacialis*) in Canadian waters and the risk of lethal entanglement. Can. J. Fish. Aquat. Sci. 68: 2174-2193.

van der Hoop, J.M., Moore,M.J., Barco, S.G., Cole, T.V.N., Daoust, P., Henry, A.G., McAlpine, D., McLellan, W.A., Wimmer, T., and Solo, A.R. 2012. Assessment of management to mitigate anthropogenic effects on large whales. Conserv. Biol. 27: 121–133.

Waring, G.T., Josephson, E., Maze-Foley, K., and Rosel, P. (eds). 2015. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2014. (Accessed August 30, 2016).

Whitehead, H. and Wimmer, T. 2005. Heterogeneity and the mark-recapture assessment of the Scotian Shelf population of northern bottlenose whale (*Hyperoodon ampullatus*). Can. J. Fish. Aquat. Sci. 62: 2573-2585.

Williams, R., Gero, S., Bejder, L., Calambokidis, J., and Kraus, S. 2011. Underestimating the damage: interpreting cetacean carcass recoveries in the context of the Deepwater Horizon/BP incident. Conserv. Lett. 4: 228–233.

Young, N.M., and Ludicello,S. 2007. Worldwide bycatch of cetaceans. U.S. Dept Commer. NOAA Tech. Memo. NMFS-OPR-36. 276 p.

TABLES

Table 1. Numbers (percent of species total) and type of incidents reported through opportunistic sightings for cetacean species in Atlantic Canada from 2008-2014 (dash indicates no observations). As explained in the text, these data provide minimum estimates of human-induced injury rates that are biased on the low side.

Name	Number of Reports	Type of Incident (percent)			Number (Percent) Dead	Number (Percent) Dead due to Unknown Cause
		Fishing Gear	Vessel Strike	Other[1]		
Mysticetes (Baleen)						
North Atlantic Right Whale	19	95	5	-	3 (16)	-
Humpback Whale	111	85	-	15	34 (30)	34 (47)
Minke Whale	114	41	-	59	77 (68)	56 (73)
Fin Whale	26	23	4	73	19 (73)	17 (89)
Sei Whale	4	50	25	25	4 (100)	1 (25)
Bowhead	1	-	-	100	1 (100)	1 (100)
Blue Whale	15	-	13	87	13 (87)	4 (31)
Large Odontocetes (Toothed)						
Pilot Whale	59	2	-	98	50 (85)	50 (100)
Sperm Whale	16	19	-	81	14 (88)	13 (93)
Northern Bottlenose Whale	5	20	-	80	4 (80)	3 (75)
Beluga	78	-	-	100	64 (82)	64 (100)
Sowerby's Beaked Whale	3	33	-	67	2 (67)	2 (100)
Whale (unspecified)	68	25	3	72	49 (72)	44 (90)
Small Odontocetes (Toothed)						
Harbour Porpoise	175	45	-	55	96 (55)	93 (97)
Atlantic White-sided Dolphin	31	-	-	100	23 (74)	-
Common Dolphin	7	14	-	86	7 (100)	6 (86)
Risso's Dolphin	1	100	-	-	-	-
Striped Dolphin	7	-	-	100	6 (86)	6 (100)
White-beaked Dolphin	75	1	-	99	54 (72)	12 (22)
Dolphin (unspecified)	8	13	-	88	4 (50)	4 (100)
Pygmy Sperm Whale	4	-	-	100	3 (75)	3 (100)
Total	827	-	-	-	527	418

1. Includes beached, stranded, floating carcasses, self-trapped, ice trapped and unspecified.

Table 2. Numbers and condition of cetaceans observed in opportunistic sightings of interactions with fishing gear and vessel strikes in Atlantic Canada from 2008-2014 (dash indicates no observations). As explained in the text, these data provide minimum estimates of human-induced injury rates that are biased on the low side.

	Fishing Gear			Vessel		
Name	**Alive**	**Alive, Injured**	**Dead**	**Alive**	**Alive, Injured**	**Dead**
Mysticetes (Baleen)						
North Atlantic Right Whale	7	8	3	-	1	-
Humpback Whale	50	26	18	-	-	-
Minke Whale	13	14	20	-	-	-
Fin Whale	-	4	2	1	-	-
Sei Whale	-	-	2	-	-	1
Bowhead	-	-	-	-	-	-
Blue Whale	-	-	-	2	-	-
Large Odontocetes (Toothed)						
Pilot Whale	-	-	1	-	-	-
Sperm Whale	2	-	1	-	-	-
Northern Bottlenose Whale	-	-	1	-	-	-
Beluga	-	-	-			-
Sowerby's Beaked Whale	-	1	-	-	-	-
Whale (unspecified)	8	3	6	-	2	-
Small Odontocetes (Toothed)						
Harbour Porpoise	75	-	3	-	-	-
Atlantic White-sided Dolphin	-	-	-	-	-	-
Common Dolphin	-	-	1	-	-	-
Risso's Dolphin	1	-	-	-	-	
Striped Dolphin	-	-	-	-	-	-
White-beaked Dolphin	1	-	-	-	-	-
Dolphin (unspecified)	1	-	-	-	-	-
Pygmy Sperm Whale	-	-	-	-	-	-

Table 3. Numbers of incidents of cetacean-gear interactions, types of gear and percent of gear-specific interactions reported through opportunistic sightings of cetaceans observed entangled or trapped in fishing gear in Atlantic Canada from 2008-2014. As explained in the text, these data provide minimum estimates of human-induced injury rates that are biased on the low side.

Species	Number of Events	Percent			
		Pot/Trap[1]	Fixed /Trap[2]	Nets[3]	Unknown[4]
Mysticetes (Baleen)					
North Atlantic Right Whale	18	11	11	0	78
Humpback Whale	94	27	17	13	43
Minke Whale	47	36	11	19	34
Fin Whale	6	50	0	0	50
Sei Whale	2	0	0	0	100
Large Odontocetes (Toothed)					
Pilot Whale	1	0	0	0	100
Sperm Whale	3	33	0	33	33
Northern Bottlenose Whale	1	0	0	100	0
Sowerby's Beaked Whale	1	0	0	0	100
Whale (unspecified)	17	6	0	12	82
Small Odontocetes (Toothed)					
Harbour Porpoise	78	0	96	3	1
Common Dolphin	1	0	0	0	100
Risso's Dolphin	1	100	0	0	0
White Beaked Dolphin	1	0	0	0	100
Dolphin (unspecified)	1	100	0	0	0

1. Lobster traps and snow crab pots.
2. Gillnet, weirs and fixed traps for herring, cod, mackerel and capelin.
3. Seines and net.
4. Ropes and buoys.

Table 4. Number of events involving cetaceans and types of gear recorded by at-sea observers during commercial fishing operations in DFO Maritimes and Quebec regions from 2008-2014 (dash indicates no observations). Numbers underestimate actual bycatch rates because they are not scaled by the size of the fishery.

	Number of Events				
Species	**Bottom Otter Trawl**	**Gillnet**	**Pelagic Longline**	**Scallop Drag**	**Snowcrab Pot**
Mysticetes (Baleen)					
Humpback Whale	-	-	-	-	1
Bowhead Whale	1	-	-	-	-
Large Odontocetes (Toothed)					
Beluga	-	1	-	-	-
Pilot Whale	3	-	2	-	-
Whale (unspecified)	-	-	-	1	-
Small Odontocetes (Toothed and Dolphins)					
Harbour Porpoise	-	1	-	-	-
Atlantic Bottlenosed Dolphin	-	-	1	-	-
Atlantic White-sided Dolphin	3	1	-	1	-
Common Dolphin	2	-	-	-	-
Risso's Dolphin	-	-	3	-	-
Dolphin (unspecified)	7	-	-	-	-

FIGURE

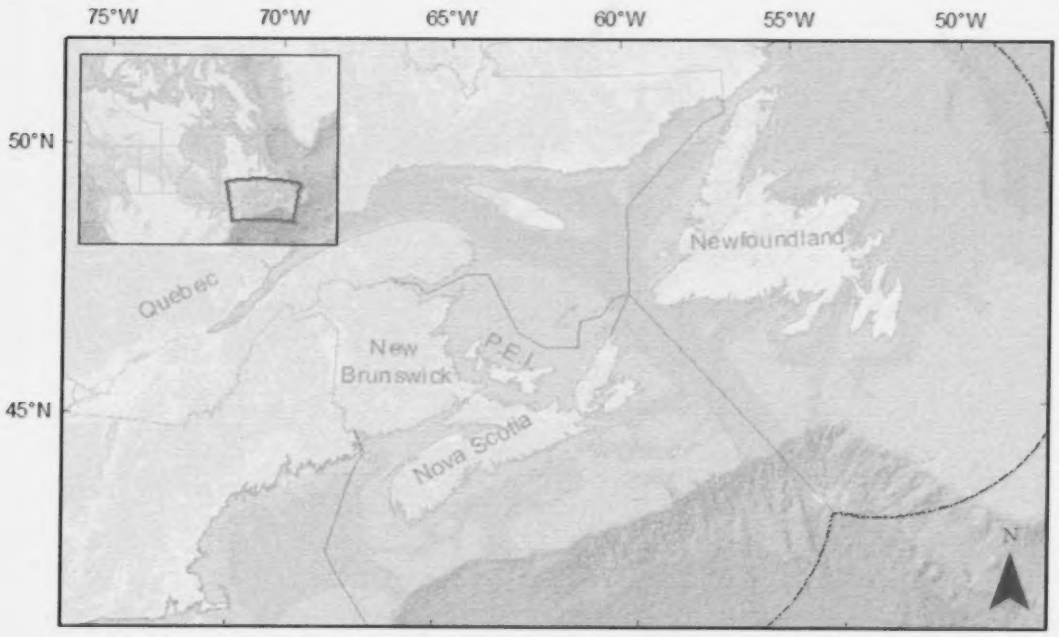

Figure 1. Map of Atlantic Canada. The four DFO regions are outlined in blue: Quebec, Gulf (Eastern and Northern New Brunswick, Northern Nova Scotia and PEI), Maritimes (Western and Southern New Brunswick and Eastern, Western, and Southern Nova Scotia), and Newfoundland and Labrador.